PATENT SPECIFICATION

(11) 1 382 300

1 382 300

(21) Application No 32128/72 (22) Filed 10 July 1972
(31) Convention Application No. 2 139 614
(32) Filed 7 Aug. 1971 in
(33) Germany (DT)
(44) Complete Specification published 29 Jan. 1975
(51) INT CL² F16F 15/02; B04B 9/12, 9/14//F16C 32/04
(52) Index at acceptance
B2P 9AX 9D1 9G
F2A 16 D36
F2S 10C3 10D3A 10D3B

(19)

(54) CONTACTLESS ROTOR ASSEMBLY

(71) We, DORNIER A.G., a German company of 799 Friedrichshafen/Bodensee, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a contactless (i.e. non-continguous) rotor assembly having a magnetic support system and a rotor with a vertical axis of rotation. In such an assembly a rotor may be freely supported by suspension from a controlled electromagnet and lateral guiding (i.e. guiding in directions at right angles to the vertical axis) may be provided by active and passive magnetic means. An elongate rotor is a rotor whose length is greater than its diameter. A gas-ultracentrifuge is an example of such a rotor. In such an assembly the maximum speed of rotation of the motor is not limited by the magnetic support system but virtually by the strength of the rotor material itself, and it is possible to reach substantially higher speeds than with a rotor mounted in roller or ball bearings.

Since during operation in an evacuated space, friction losses are small, the necessary driving power required for the magnetic support system in a contactless rotor assembly is correspondingly small. A coolant circuit is also not required for the support. Oil lubricated bearings are of little use in a gas-ultracentrifuge since, in the event of a failure involving fall of the rotor, the lubricant from the bearings could enter the gas circuit and cause contamination and wear. To eliminate this disadvantage it would be necessary for a mechanical support system to use lubricant requiring a more elaborate method of application, viz. special oil which may be costly.

A magnetic support system by which the rotor of a centrifuge is freely suspended under an electromagnet is known, see for example U.S. Patent Specification No. 2,733,857. The radial dimension of the rotor in question is large as compared with its axial length. According to gyroscopic law a high speed elongate element will always tend to rotate in course of time about the axis of its highest moment of inertia. Should a rotor not rotate about that axis, the slightest disturbance is sufficient to force it to rotate about that axis. Since according to gyroscopic law an elongate rotor is not stable in operation, means for adequate damping of precessional and nutational motions of the rotor are required.

Another magnetic support system is known, see German Patent Specification No. 1,750,602 in which the rotor is supported by one or several permanent magnets acting on ferromagnetic parts of the rotor. However, a constant vertical level of the rotor cannot be ensured by this system since it is a passive, unregulated system. The maintenance of a constant vertical level of the rotor is necessary for efficient operation.

It is an object of the invention to provide an assembly in which the rotor is supported with small losses at a substantially constant vertical level, and to provide for stable behaviour at a high speed of rotation. Though a vertical magnetic suspension system for a rotor is known, the mechanical parts, however, are arranged laterally of the rotor, see for example German Patent Specification No. 872,137. High oil consumption and friction are a drawback in these systems, the support being only partly by magnetic force.

According to this invention there is provided a rotor assembly comprising an elongate rotor having a vertical axis of rotation and a magnetic support system for the rotor, wherein the rotor is suspended by the magnetic action of the support system on a body which is connected to the upper end of the rotor and which has a convex upper surface maintained by the magnetic action at a given minimum distance from the sup-

port system, the radius of curvature of the upper surface being such as in use to accommodate the nutational and/or precessional motion of the rotor, and wherein a device for damping the said motion of the rotor is disposed at or near one end of the rotor.

The invention will now be described by way of example, with reference to the accompanying drawing, the single Figure of which is a diagrammatic vertical axial section of a gas-ultra-centrifuge.

An elongate rotor 2, driven by a motor 3, diagrammatically indicated, is arranged in a stationary housing 1. The drive is through a rotor disc 4 rigidly mounted on the rotor 2. This drive is known and need not be further described. The rotor 2 runs in a vacuum to reduce gas friction. The evacuated space between the housing 1 and the rotor 2 is indicated by 5.

The rotor 2 is supported by being freely suspended by a support body 6 under a magnet system 7. The type of magnet system is without special relevance to the invention. A pot-shaped electromagnet is shown by way of example. A given minimum distance between the magnet system 7 and the support body 6 is determined by means of known inductive, capacitative or optical distance measuring devices and is fed as a value to a controller. The output signal of the controller influences the magnet system 7 so that the given minimum distance is maintained.

The support body 6, arranged opposite the magnet system 7, is a circular disc and has a convex upper surface, the radius of curvature of which is such that variation of the position of the support body 6 or of the rotor 2 relative to the stationary magnet system 7 virtually does not lead to alteration of the given minimum distance, as would be the case with a flat surfaced support body. The radius of curvature of the upper surface is such as substantially to accommodate the nutational and/or precessional motion of the rotor.

The vertical arrangement of the rotor 2 has the advantage that disturbances, caused for instance by vibration or rotor traction variation through the drive motor 3, can be controlled. This advantage is enhanced by the above-mentioned arrangement of the magnet system 7 as a pot-shaped magnet, whereby, on rotation of the rotor, no eddy currents are induced owing to the active load carrying capacity, and a correspondingly lower driving power is sufficient. Neutralisation of vertical support and lateral guiding may be obtained, since the active vertical support does not generate any component of force in the lateral guiding direction.

Two permanent magnet means are used for the lateral (radial) guiding (location) of the rotor 2, mounted respectively at the ends of the rotor 2. Each means comprises an annular permanent magnet 8 fixed to the rotor and an annular permanent magnet 9 loosely mounted in the housing and close to the magnet 8. Each annular magnet 9 is suspended as shown in an oil-filled, totally enclosed container 10 to provide for damping, but this is sufficiently effective only at comparatively low speed, and is supplemented by an additional damping device for damping high frequency vibration of the rotor occurring at high speed. A damping device for nutational motion can serve this purpose. This damping device comprises at least one distance sensor or measuring device 11 which may be inductive, capacitative or optical, an automatic control unit 12 and a regulating unit 13. The measuring device 11 monitors deviation of the rotor 2 caused by nutation and/or precession. The regulating unit 13, which is an electromagnet, is controlled by the automatic control unit 12 in such a way that the high frequency forms of vibration are damped by the action of the electromagnet upon the ferromagnetic wall of the rotor.

This damping device 11, 12, 13 is required only at one end of the rotor, and as shown is at the lower end. This damping device is effective only in the lateral direction.

According to another embodiment, it is possible to have in the damping device 11, 12, 13, instead of only one regulating unit 13, two such regulating units, staggered by 180°, and to control these two regulating units by a push pull arrangement. It is also possible to offset the distance sensor 11 from the regulating device 13 by a given angle, in the direction of rotation of the rotor. A further improvement in damping is achieved in this way. The size of the angle is a function of the gyroscopic behaviour of the rotor.

To ensure that any expansion of the rotor wall (occurring during operation as a result of centrifugal force) will not affect functioning of the damping device 11, 12, 13, the distance sensor 11 can be arranged as a bridge connection.

Such an uniaxially acting damping device 11, 12, 13 is distinguished by its simplicity. It is also possible to provide the damping device in one self-contained unit, which is important for the application of the magnetic support system in a gas-ultra-centrifuge, where an installation may have a great number of individual centrifuges and where, by using such dimple damping devices, considerable economy can be achieved as compared with the known fully active lateral guiding systems.

The application of the rotor assembly of the invention is not limited to gas-

ultracentrifuges, but is suitable for rotors of other form, for instance, a turbo-molecular-pump or a gyroscopic device where, according to requirements, ferromagnetic parts are fitted to the rotor upon which the magnetic forces can act.

WHAT WE CLAIM IS:—

1. A contactless rotor assembly comprising an elongate rotor having a vertical axis of rotation and a magnetic support system for the rotor, wherein the rotor is suspended by the magnetic action of the support system on a body which is connected to the upper end of the rotor and which has a convex upper surface maintained by the magnetic action at a given minimum distance from the support system, the radius of curvature of the upper surface being such as in use to accommodate the nutational and/or precessional motion of the rotor, and wherein a device for damping the said motion of the rotor is disposed at or near one end of the rotor.

2. An assembly according to claim 1, wherein the body is a circular disc.

3. An assembly according to claim 1 or claim 2, wherein the magnetic support system is stationary.

4. An assembly according to claim 2, wherein the disc and rotor have a common axis of rotation.

5. An assembly according to any preceding claim, wherein the magnetic support system includes a pot magnet with a central core.

6. An assembly according to claim 5, wherein the pot magnet and the rotor have a common axis.

7. An assembly according to claim 1, wherein the damping device includes an electromagnet disposed so as to be effective on the rotor.

8. An assembly according to claim 1, wherein the damping device includes two electromagnets disposed so as to be effective on the rotor and disposed 180° apart and operated by a push pull device.

9. An assembly according to claim 7 or claim 8, wherein the damping device includes at least one distance sensor angularly offset around the rotor by a given amount from the or each electromagnet, the or each sensor being adapted to pass a signal to a control device which in turn controls the or each electromagnet.

10. An assembly according to claim 9, wherein the or each sensor is inductive, capacitative, or optical.

11. An assembly according to any preceding claim, wherein a lateral guiding system includes at each end of the rotor magnetic means for guiding the rotor.

12. An assembly according to claim 11, wherein each magnetic means comprises an annular permanent magnet on the rotor and an associated annular permanent magnet in a rotor housing of the assembly.

13. An assembly according to claim 12, wherein each annular permanent magnet in the rotor housing is suspended in damping liquid in a totally enclosed container.

14. A rotor assembly constructed and arranged substantially as herein described and shown in the accompanying drawing.

15. A gas ultracentrifuge having a rotor assembly according to any preceding claim.

WITHERS & ROGERS,
Chartered Patent Agents,
148—150 Holborn,
London, EC1N 2NT.
Agents for the Applicants.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1975.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

13822300 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*